APTD-0825

PB 207 694

OKLAHOMA CITY METROPOLITAN AREA AIR POLLUTANT EMISSION INVENTORY

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68

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-0825	2.	3. Recipient's Accession No.
4. Title and Subtitle Oklahoma City Metropolitan Area Air Pollutant Emission Inventory			5. Report Date February 1970 6.
7. Author(s) Michael J. McGraw			8. Performing Organization Rept. No.
9. Performing Organization Name and Address U. S. Department of Health, Education, and Welfare National Air Pollution Control Administration Division of Air Quality and Emission Data Durham, North Carolina			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Same			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

A summary report is presented of the emission inventory for the Oklahoma City Metropolitan Area. The report provides estimates of the present levels of air pollutant emissions and status of their control. The pollutants which include sulfur oxides, particulates, carbon monoxide, hydrocarbons, and nitrogen oxides are delineated with respect to source type, season of the year, and geographical distribution within the area. The Study Area, which was chosen on the basis of the distribution of population and air pollution sources, consists of nine counties surrounding Oklahoma City. A grid coordinate system was used to show the geographical distribution of emissions within counties. All sources of emissions were classified into five categories: transportation, stationary fuel combustion, solid-waste disposal, industrial processes, and evaporative losses.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Emission
Inventories
Sulfur oxides
Particles
Carbon monoxide
Hydrocarbons
Nitrogen oxides
Sources
Seasonal variation
Transportation
Fuels
Combustion
Waste-disposal
Industrial plants
Evaporation

17b. Identifiers/Open-Ended Terms

Oklahoma City, Oklahoma
Stationary sources
Particulates

Details of illustrations in this document may be better studied on microfiche

17c. COSATI Field/Group 13B

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	UNCLASSIFIED	66
	20. Security Class (This Page) UNCLASSIFIED	22. Price

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Prepared by
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PUBLIC HEALTH SERVICE
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National Air Pollution Control Administration
Division of Air Quality and Emission Data
Durham, North Carolina
February, 1970

ACKNOWLEDGMENTS

Sincere gratitude is extended by the National Air Pollution Control Administration to the many individuals and companies who contributed to this study.

Special thanks are due to Keith Stanley of the Oklahoma City County Health Department and Robert Blanche and Doyle McWhirter of the Oklahoma State Department of Health, who contributed invaluable assistance in the gathering of data for this report.

PREFACE

This report, which presents the emission inventory for the Oklahoma City Metropolitan Area, is another in a series of surveys outlining the sources and emissions of air pollutants for major metropolitan areas in the country. These surveys, conducted by the National Inventory of Air Pollutant Emissions and Control Branch of the National Air Pollution Control Administration, provide estimates of the present levels of air pollutant emissions and status of their control. The pollutants which include sulfur oxides, particulates, carbon monoxide, hydrocarbons and nitrogen oxides, are delineated with respect to source type, season of the year and geographical distribution within the area. The general procedure for the surveys is based upon the rapid survey technique for estimating air pollutant emissions.[1] These reports are intended to serve as aids in the proposing of boundaries of Air Quality Control Regions, as directed by the Air Quality Act of 1967.

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INTRODUCTION

This report is a summary of the Oklahoma City air pollutant emission inventory conducted in September 1969. Since all inventories are based upon a calendar year, the data and emission estimates presented are representative of 1968 and should be considered as indicating the conditions as existed during that year.

The Study Area, which was chosen on the basis of the distribution of population and air pollution sources, consists of nine counties surrounding Oklahoma City. This area covers approximately 7,200 square miles and had a 1968 population of 736,000.

A grid coordinate system was used to show the geographical distribution of emissions within counties. The Study Area was subdivided into 77 grid zones ranging in size from 25 square kilometers in the heavily populated and industrialized areas to 400 square kilometers in the rural areas.

All sources of emissions were classified into five categories--transportation, stationary fuel combustion, solid-waste disposal, industrial processes and evaporative losses. Each of these source categories was divided into two subgroups--point sources and area sources. Facilities, which emit large quantities of air pollutants, were considered individually as point sources, while the many remaining contributors such as motor vehicles, residential and commercial fuel users, small industries and on-site refuse burning equipment, were considered collectively as area sources. For this report, fourty-eight individual sources, which had emissions greater than 0.5 tons per average annual day for any pollutant, were classified as point sources.

Emissions were estimated by using various indicators such as fuel consumption, refuse burning rates, vehicle-miles, production data, and control efficiencies and emission factors relating these indicators to emission rates.[2] These factors represent average emission rates for a particular source category. Since individual sources have inherent differences that cannot always be taken into consideration, discrepancies between the actual

and estimated emissions are more likely in individual sources than in the total emissions for a source category.

As in all emission surveys, the data presented are estimates and should not be interpreted as absolute values. The estimates are, in some cases, partial totals due to the lack of emission factors and production or consumption data. Despite these limitations, these estimates are of sufficient accuracy and validity in defining the extent and distribution of air pollutant emissions in the Study Area.

SUMMARY

The annual emissions as estimated by the Oklahoma City Metropolitan Area Air Pollutant Emission Inventory are:

1.	Sulfur Oxides	2,200 tons
2.	Particulates	14,200 tons
3.	Carbon Monoxide	429,700 tons
4.	Hydrocarbons	150,700 tons
5.	Nitrogen Oxides	43,600 tons

The following is a brief description of the air pollutant emissions as presented in Table 1 and Table 2.

Sulfur Oxides: In the Study Area natural gas is essentially the only fuel used. Since sulfur oxide emissions are practically non-existant from the burning of this fuel, the contribution to total sulfur oxide emissions from stationary fuel combustion was negligible.

The only significant source of sulfur oxides was transportation sources. Motor vehicles, by far the largest source category, contributed approximately 84 percent of the total sulfur oxide emissions. Aircraft and railroads accounted for 8 percent of the total emissions while the disposal of refuse by incineration and open burning also accounted for 8 percent.

Particulates: Individual sources of particulates from industrial processes accounted for almost 50 percent of the total particulate emissions in the Oklahoma City Study Area. Even though this area was void of any heavy industry, it did have a large number of plants in the food and

agricultural industry and the mineral products industry. The largest sources in these industries were fertilizer plants, grain elevators, and rock processing operations accounting for 8 percent, 15 percent and 13 percent, respectively, of the total particulate emissions.

Again, since natural gas was the only fuel used, the contribution to total particulate emissions from stationary fuel combustion was under 8 percent. Transportation sources accounted for 29 percent of total particulate emissions and refuse disposal, 15 percent.

Carbon Monoxide: In most metropolitan areas the largest source of carbon monoxide emissions is from automobiles and other motor vehicles. This was also true in Oklahoma City as motor vehicles contributed 93 percent of the carbon monoxide emitted annually. Other transportation sources including railroad and aircraft operations contributed another 4 percent.

The only other significant source of carbon monoxide was from the inefficient combustion of refuse at open burning dumps and backyard incinerators. This category accounted for about 2 percent of the total emissions.

Hydrocarbons: The Oklahoma City Study Area is almost saturated with small crude oil production wells. These wells, even though essentially closed systems, do emit hydrocarbon vapors from evaporation. It was estimated that over one-third of the total hydrocarbon emissions could be contributed to this crude production. The area also has numerous LPG processing plants which emit hydrocarbons. These plants accounted for over 17 percent of the total hydrocarbon emissions.

Evaporative losses from automobiles which includes

losses from the gas tank, carburetor and engine crankcase accounted for 12 percent of total hydrocarbon emissions. Other smaller evaporative loss sources gasoline storage and handling, industrial solvent usage, dry cleaning plants, miscellaneous solvent usage, and the storage of crude oil, collectively accounted for 10 percent of the total hydrocarbon emissions.

Exhaust gases from motor vehicles was a primary source of hydrocarbon emissions, accounting for over 20 percent of the total. Other sources included the open burning of solid waste and railroad and aircraft operations which accounted for 3 and 2 percent, respectively, of total emissions.

Nitrogen Oxides: The major source of nitrogen oxides was the exhaust gas from motor vehicles, which contributed over 55 percent of the total emissions.

Natural gas combustion, while not a significant source of other pollutants is a large source of oxides of nitrogen. In the Oklahoma City Study Area this source accounted for 41 percent of the total nitrogen oxides emissions. Of this 41 percent, 33 percent came from the two steam-electric plants in the Study Area.

The remaining 4 percent of the total nitrogen oxides came from the disposal of refuse by incineration and open burning.

TABLE 1 SUMMARY OF AIR POLLUTANT EMISSIONS IN THE OKLAHOMA CITY STUDY AREA, 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	1,880	3,290	399,300	31,300	22,100
Other	180	770	19,400	4,500	2,040
Subtotal	2,060	4,060	418,700	35,800	24,140
Stationary Fuel Combustion					
Industry	N	100	N	N	1,150
Steam-Electric	10	560	N	N	14,440
Residential	N	290	N	N	1,840
Commercial and Institutional	N	110	N	N	690
Subtotal	10	1,060	N	N	18,120
Refuse Disposal					
Incineration	50	240	1,070	20	70
Open Burning	120	1,850	9,870	3,480	1,280
Subtotal	170	2,090	10,940	3,500	1,350
Process Losses	N	7,000	90	N	N
Evaporative Losses	--	--	--	111,400	--
GRAND TOTAL[a]	2,200	14,200	429,700	150,700	43,600

N = Negligible

a = Totals have been rounded to nearest 100 tons/year.

TABLE 2 PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN THE OKLAHOMA CITY STUDY AREA

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	83.9	23.2	92.9	20.8	50.7
Other	8.0	5.4	4.5	3.0	4.7
Subtotal	91.9	28.6	97.4	23.8	55.4
Stationary Fuel Combustion					
Industry	N	0.7	N	N	2.6
Steam-Electric	0.5	3.9	N	N	33.1
Residential	N	2.0	N	N	4.2
Commercial and Institutional	N	0.8	N	N	1.6
Subtotal	0.5	7.4	N	N	41.5
Refuse Disposal					
Incineration	2.2	1.7	0.3	N	0.2
Open Burning	5.4	13.0	2.3	2.3	2.9
Subtotal	7.6	14.7	2.5	2.3	3.1
Process Losses	N	49.3	N	N	N
Evaporative Losses	0.0	0.0	0.0	73.9	0.0
TOTAL	100	100	100	100	100

N = Negligible

DESCRIPTION OF STUDY AREA

The Study Area for the emission survey of the Oklahoma City Metropolitan Area consists of nine counties--Canadian, Cleveland, Grady, Kingfisher, Lincoln, Logan, McClain, Oklahoma and Pottawatomie. The nine-county area is located in the central part of Oklahoma. Figure 1 shows the location of the Oklahoma City Study Area relative to other large cities in its vicinity.

Figure 2 represents a more detailed drawing of the Oklahoma City Study Area showing the major urban areas. It should be pointed out that the boundaries of these areas do not correspond to city limits, but rather give a general outline of the major clusters of population. The Study Area occupies 7,280 square miles and contained an estimated 1968 population of 735,800, which is approximately a 14 percent increase since 1960 (Table 2).[3] The population density map (Figure 3) shows the heaviest concentrations near Oklahoma City.

TOPOGRAPHY

The Oklahoma City Metropolitan Area is located along the North Canadian River in a minor valley at the geographic center of the State. The surrounding country is gently rolling with the nearest hills or low mountains, the Arbuckles, 80 miles south. Although the Oklahoma City Area is fortunate in not being enclosed by towering mountains on any side, the minor valley in which it is located plays somewhat of a role in the entrapment of pollution in the city.

CLIMATOLOGY

The climate of the Study Area falls mainly under continental control characteristics of the Great Plains Region. The continental effect produces pronounced daily and seasonal temperature changes and considerable variation in seasonal and annual rainfall. Summers are long and usually hot. Winters are comparatively mild and short. The prevailing winds are southerly and

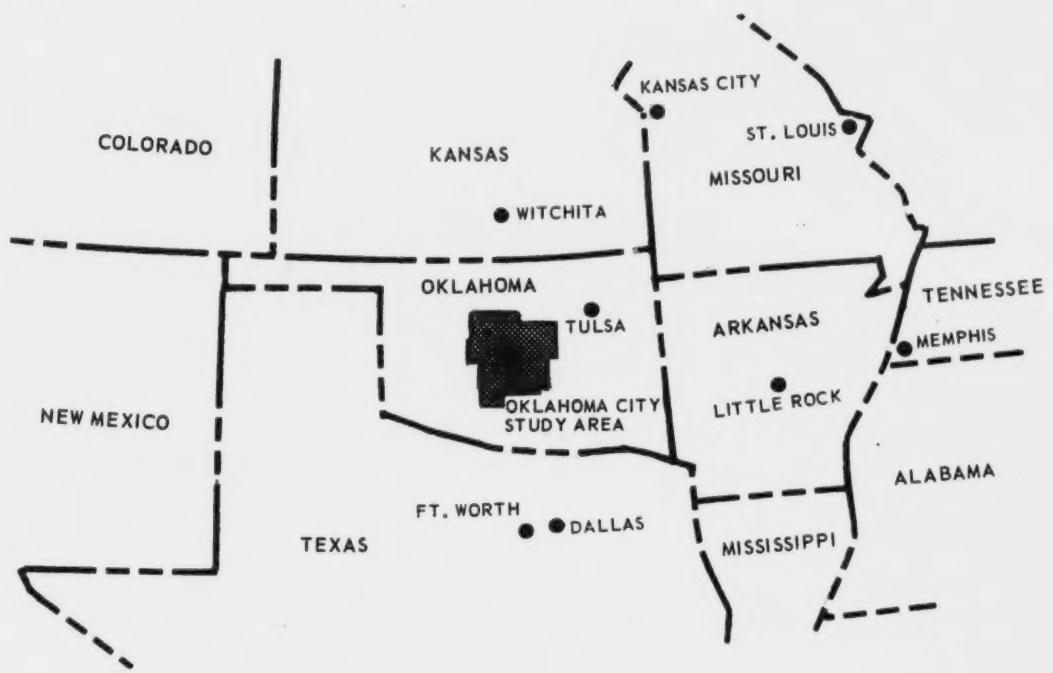

Figure 1. Oklahoma City study area and surrounding cities.

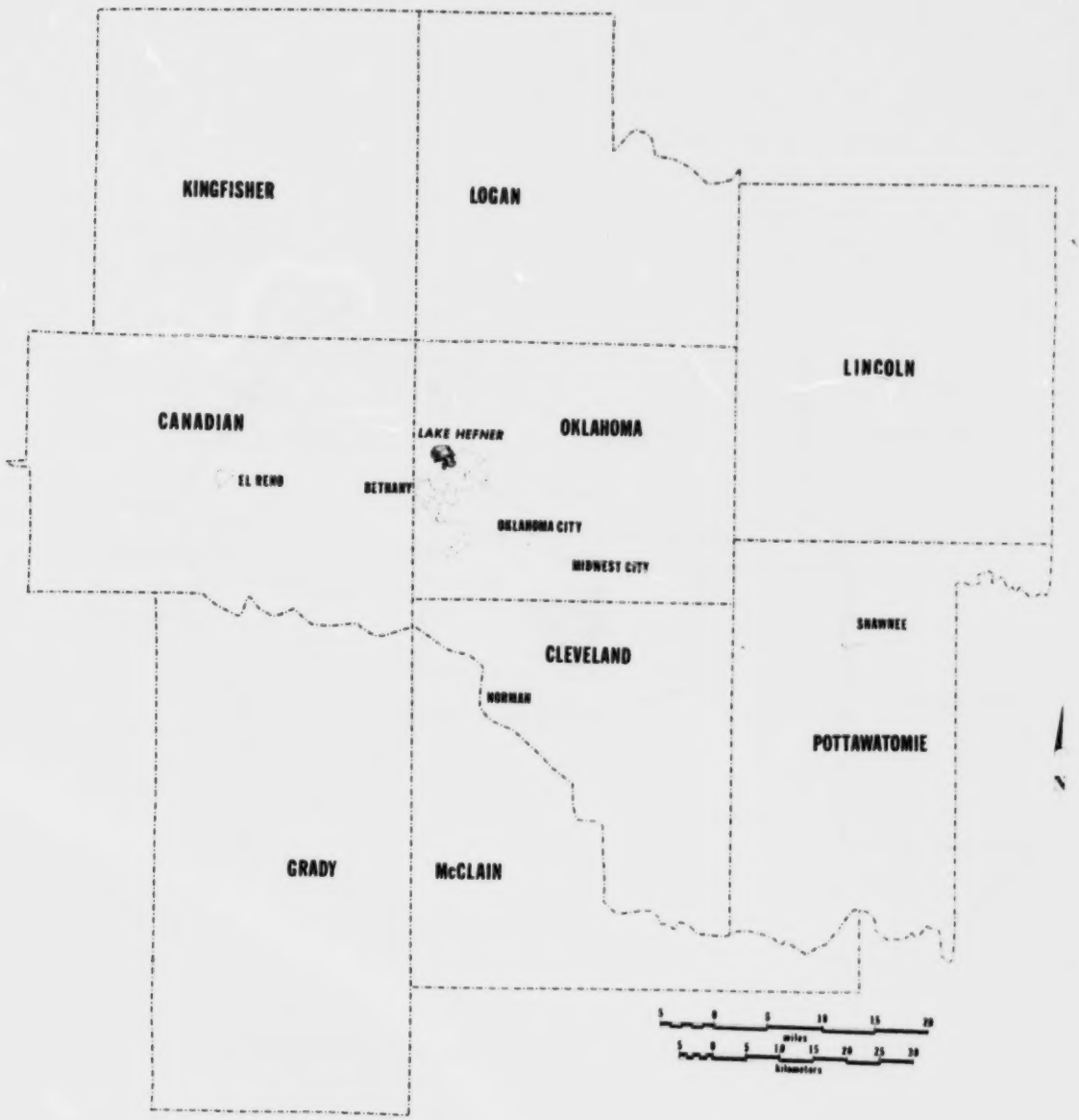

Figure 2 Detailed Map of Oklahoma City Study Area

TABLE 3 AREA AND POPULATION CHARACTERISTICS FOR THE OKLAHOMA CITY STUDY AREA

County	Land Area sq. mi.	Population 1960	Population 1968	Population Density (1968)
Canadian	897	24,700	31,400	35
Cleveland	541	47,600	76,000	140
Grady	1,096	29,600	30,000	27
Kingfisher	904	10,600	12,600	14
Lincoln	973	18,800	19,500	20
Logan	751	18,700	18,100	24
McClain	573	12,700	13,400	23
Oklahoma	705	439,500	493,000	700
Pottawatomie	794	41,500	41,800	53
STUDY AREA	7,234	643,700	735,800	102

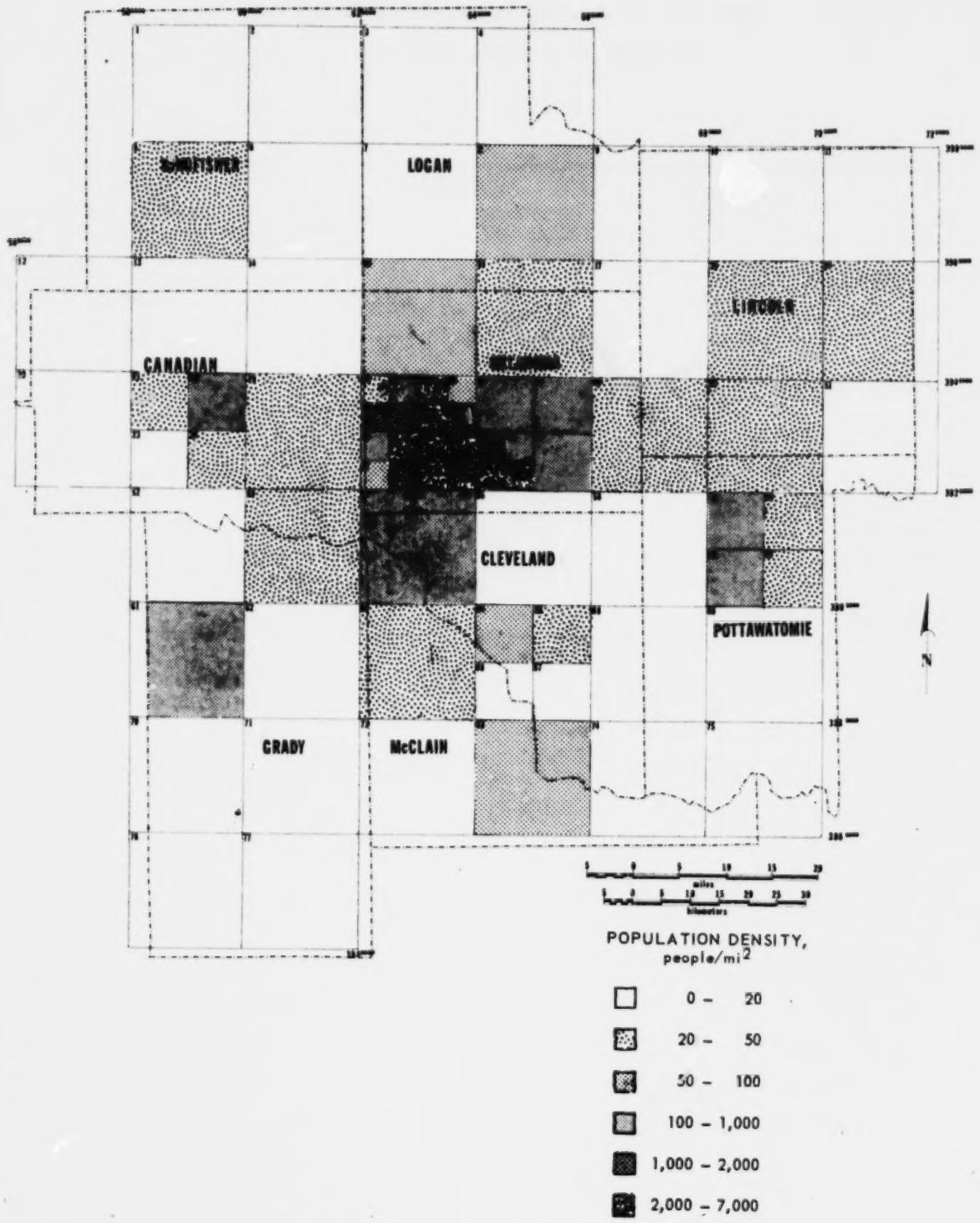

Figure 3 . Population densities for the Oklahoma City study area, 1968.

they are usually brisk, averaging 14 mph in the fall and winter, 16 mph in the spring and 12 mph in the summer. In general, the climatological conditions in the Oklahoma City Study Area are not conducive for the accumulation of large concentrations of pollutants, but lend themselves more towards dispersion of the emissions away from the area.

MAJOR INDUSTRIAL FACTORS

Table 4 shows selected manufacturing establishments in the Study Area by county for 1963.[4] The area is notably void of any heavy industry and is characterized by the large number of food and agricultural plants. It may be noted from the table that Oklahoma County accounts for the largest single percentage of every type of manufacturing. At least 75 percent of the establishments of any type are located in Oklahoma County.

TABLE 4 SELECTED MANUFACTURING ESTABLISHMENTS IN THE OKLAHOMA CITY STUDY AREA

Jurisdiction	Number of Establishments with 20 or More Employees						
	Food and Tobacco	Paper and Printing	Wood Products	Stone Products	Metal Products	Machinery	Total
Canadian	2	--	--	--	--	1	3
Cleveland	3	3	--	--	--	--	6
Grady	3	1	--	--	--	2	6
Kingfisher	--	--	--	--	--	--	--
Lincoln	--	--	---	1	--	--	1
Logan	--	--	1	--	--	--	1
McClain	--	--	--	--	--	--	--
Oklahoma	46	14	10	11	25	28	134
Pottawatomie	2	1	--	--	1	1	5
Study Area	56	19	11	12	26	32	156

GRID COORDINATE SYSTEM

A grid coordinate system, based on the Universal Transverse Mercator Projection (UTM) was used in the Oklahoma City Study Area to show the geographical distribution of emissions. A map of this grid system is presented in Figure 4.

The UTM system was chosen due to its advantages over other standard grid systems such as the Latitude-Longitude and State Plane Coordinate Systems. The major advantages of this system are that (1) it is continuous across the country and is not hindered by political subdivisions, (2) the grids are of uniform size throughout the country, (3) it has world-wide use, and (4) the grids are square in shape--a necessary feature for use in meteorological dispersion models.

The Universal Transverse Mercator Projection is based upon the metric system. Each north-south and east-west grid line, as illustrated in Figure 4, is identified by a coordinate number expressed in meters. Each point source and grid is identified by the horizontal and vertical coordi- of their geographical center to the nearest 100 meters.

As shown in Figure 4, the Study Area was divided into 77 grids of three different sizes--25,100, and 400 square kilometers. Grid zones of different sizes are used to limit the number of grid zones and yet allow a satisfactory definition of the geographical gradation of emissions. The majority of the emissions is usually concentrated in the populated and industrialized portions of a Study Area. Smaller grids are placed over these areas in order to reflect abrupt changes in emissions within short distances. The use of grid zones smaller than 25 square kilometers is not warranted because of the inherent inaccuracies in the data. Since only a small percentage of the total emissions occur in rural areas, larger grid zones are normally used to show the distribution of emissions in these lightly populated portions of a Study Area.

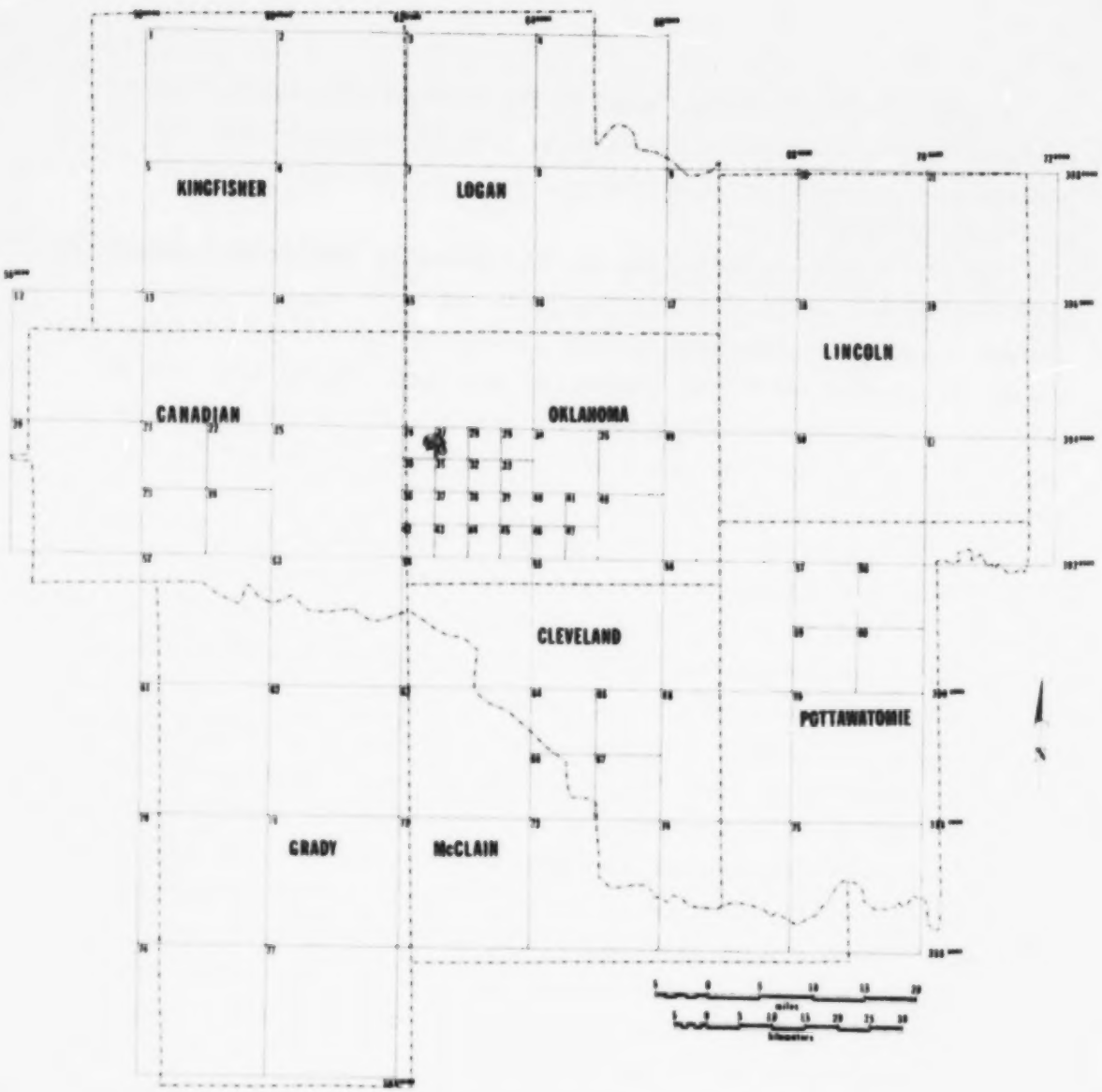

Figure 4 Grid Coordinate System for Oklahoma City Study Area

EMISSIONS BY CATEGORY

For the purposes of compiling the basic data and emission estimates, the air pollutant sources were classified into the following five categories:

1. Stationary fuel combustion
2. Transportation
3. Solid waste disposal
4. Industrial processes
5. Evaporative losses

Each of these categories is considered individually in this section where data sources are given and methods of calculation discussed.

STATIONARY FUEL COMBUSTION

The stationary fuel combustion category is concerned with any fixed source which burns fuels for either space heating or process heating. The four primary sources in this category are industrial facilities, steam-electric plants, residential housing, and commercial and institutional establishments. In the Oklahoma City area, natural gas and liquified petroleum gas were primarily the only fuels used. Table 5 and Table 6 present a summary of the fuels consumed in the Study Area.

Steam-Electric Utility

METHODOLOGY: Data on the two power plants in the area were acquired from the Oklahoma State Health Department and compared to figures presented by the National Coal Association.[5] The data included the annual fuel consumption for 1968 and the method of firing employed at each plant.

RESULTS: The two steam-electric generating plants in the Oklahoma City area consumed over 60 percent of the total natural gas utilized by all sources. Air pollutant emissions from fuel combustion at these plants as well as from all other fuel combustion sources are summarized in Table 7. The steam-electric plants were significant sources of particulate and nitrogen oxides. Over 80 percent of the total nitrogen oxides from stationary fuel combustion and 50 percent of the particulates were attributed to these two plants.

TABLE 5 NATURAL GAS CONSUMPTION BY COUNTY, 1968 (MILLION CF/YEAR)

Political Jurisdiction	Residential	Industrial	Steam-Electric	Commercial & Institutional	Total
Canadian	770	140	--	410	1,320
Cleveland	2,020	1,320	--	1,200	4,540
Grady	900	120	--	310	1,330
Kingfisher	230	260	--	130	620
Lincoln	400	20	--	70	490
Logan	520	130	--	230	880
McClain	230	30	--	70	330
Oklahoma	19,300	8,570	74,100	9,090	111,060
Pottawatomie	1,230	190	--	430	1,850
TOTAL	25,600	10,780	74,100	11,940	122,420

TABLE 6 DOMESTIC CONSUMPTION OF LPG BY COUNTY, 1968 (Gal/Year)

Political Jurisdiction	Residential LPG Use
Canadian	1,910,000
Cleveland	1,420,000
Grady	2,550,000
Kingfisher	1,210,000
Lincoln	1,440,000
Logan	650,000
McClain	1,630,000
Oklahoma	4,300,000
Pottawatomie	1,810,000
TOTAL	16,920,000

TABLE 7 AIR POLLUTANT EMISSIONS FROM STATIONARY FUEL COMBUSTION IN STUDY AREA, 1968 (TONS/YEAR)

Fuel User	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Natural Gas					
Industrial	N	100	N	N	1,150
Steam-Electric	10	560	N	N	14,440
Residential	N	240	N	N	1,490
Commercial and Institutional	N	110	N	N	690
Subtotal	10	1,010	N	N	17,770
LPG					
Residential	N	50	N	N	350
GRAND TOTAL	10	1,060	N	N	18,120

N = Negligible

Industrial

METHODOLOGY: Natural gas numbers were obtained from each of the local suppliers who provided the breakdown by user category. Since natural gas, for all practical purposes, was the only fuel used by industry, no other contacts were necessary. No specific data on the natural gas consumption by individual plants was obtained. It was assumed that all industrial fuel consumption was an area source and was apportionned onto grids based on industrial land use.

It should be noted that fuel combustion by industries includes both fuel used for space heating, and fuel used for process heating. A national average was used to separate process heating from space heating.

RESULTS: The emissions from the combustion of natural gas were almost insignificant contributing less than 10 percent of the stationary fuel combustion emissions for any pollutant.

Residential

METHODOLOGY: Natural gas and LPG, for all practical purposes, were the only fuels used for residential home heating. There were homes heated by other fuels, but they represent a very small percentage of the total. Data on the amount of natural gas used for domestic heating was supplied by the local power companies and compared with the rapid survey technique of estimating the fuel used for residential heating.[6] LPG consumption data was estimated based on the rapid survey technique.

RESULTS: Residential sources accounted for 20 percent of the total particulates from stationary fuel combustion, and 10 percent of the nitrogen oxides. Sulfur oxides, carbon monoxide and hydrocarbons were negligible from residential heating.

Commercial and Institutional

METHODOLOGY: Commercial and institutional establishments use primarily natural gas as the only fuel. Data on the amount of natural gas used by these establishments were provided by the local power company.

RESULTS: Since commercial and institutional sources use only natural gas for their space heating, this was not a significant source of pollution.

TRANSPORTATION

Three types of transportation sources of air pollution are considered in this survey--motor vehicles, aircraft, and railroads. Motor vehicles, which are by far the most significant source in this category, are further subdivided according to type of fuel--gasoline or diesel.

Motor Vehicles

More than 12 million miles were traveled by motor vehicles in 1968 in the Oklahoma City Study Area. In the process, 322 million gallons of gasoline and 27 million gallons of diesel fuel were consmed for highway purposes. Table 8 shows the miles of travel for gasoline and diesel vehicles for each county in the Study Area.

Vehicle-mile data for essentially all of the roads in Oklahoma County were supplied by the State Highway Department. For Oklahoma County, this data was in the form of traffic flow maps which showed average daily traffic along the roads. In the remaining counties, vehicle-mile information was not available, and thus gasoline consumption was used to find vehicular emissions.[7]

The contribution to the total motor vehicle pollution by diesel-powered vehicles was determined by assuming that approximately three percent of the total vehicle miles traveled were by diesel-powered vehicles. This was checked by estimating diesel fuel consumption in each county. These emissions were apportionned on a grid basis by assuming they were proportional to gasoline emissions.

Emissions from motor vehicles are a function of the speed at which the vehicle travels. Average speeds of 10-20 mph were assumed for downtown areas, 20-30 mph for the residential areas, and 30-45 mph for the rural areas to calculate vehicle emissions.

From all transportation sources, motor vehicles accounted for 65 percent of the sulfur oxides, 44 percent of the particulates, 95 percent of the carbon monoxide, 82 percent of the hydrocarbons, and 79 percent of the nitrogen oxides. Gasoline powered motor vehicles contributed a greater percent of all pollutants than diesel powered motor vehicles. Emissions from transportation sources are summarized in Table 9.

TABLE 8 VEHICLE MILES OF TRAVEL FOR MOTOR VEHICLES IN THE OKLAHOMA CITY STUDY AREA, 1968 (THOUSAND VEHICLE MILES PER DAY)

Political Jurisdiction	Gasoline Vehicle Miles	Diesel Vehicle Miles	Total
Canadian	620	20	640
Cleveland	970	30	1,000
Grady	440	10	450
Kingfisher	240	10	250
Lincoln	340	10	350
Logan	290	10	300
McClain	220	10	230
Oklahoma	8,490	260	8,750
Pottawatomie	680	20	700
TOTAL	12,290	380	12,670

TABLE 9 AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES
1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Motor Vehicles					
Gasoline	1,340	1,790	398,460	29,500	19,100
Diesel	540	1,500	820	1,840	3,020
Subtotal	1,880	3,290	399,280	31,340	22,120
Aircraft					
Jet	--	180	280	310	160
Piston	--	90	18,900	3,600	880
Turboprop	--	N	N	N	N
Subtotal	--	270	19,180	3,910	1,040
Railroads	180	500	270	610	1,000
GRAND TOTAL	2,060	4,060	418,730	35,860	24,160

N = Negligible

Aircraft

Table 10 shows the air traffic activity at the largest airports in the Study Area. An estimate of the number of flights by engine type was supplied by the traffic controller at each airport and summarized in Table 10.

The air pollutant emissions from aircraft include all phases of operation (taxi, take-off, climb out, approach and landing) that take place below the arbitrarily chosen altitude of 3,500 feet. Emissions at cruise altitude (above 3,500 feet) are not of concern in an emission inventory. From all transportation sources, aircraft accounted for 6 percent of the particulates, 4 percent of the carbon monoxide, 10 percent of the hydrocarbons and 4 percent of the nitrogen oxides.

Railroads

Railraod operations (mainly locomotive) consume about 9 million gallons of diesel fuel per year within the Study Area. This quantity is about 60 percent less than the amount of diesel fuel consumed by motor vehicles. The majority of this fuel is consumed during switching operations. Diesel fuel consumption data were supplied by each of the major railraods in the Oklahoma City area.

Railroad operations contribute about 12 percent of the particulates from all transportation sources. They account for less than 4 percent of the emissions for any other pollutant.

SOLID WASTE DISPOSAL

Approximately 654,000 tons of refuse was generated during 1968 within the Study Area. Table 11 presents a solid waste balance for the Oklahoma City Study Area, showing the various methods of disposal and the quantities disposed of by each method. The bulk of the refuse in Oklahoma, Canadian and Cleveland Counties was disposed of by landfills, whereas in all other counties it was burned in open burning dumps. Refuse data for all of the counties except Oklahoma County were supplied by the State Department of Solid Waste. For Oklahoma County the Oklahoma City-County Health Department supplied the numbers.

TABLE 10 AIR TRAFFIC ACTIVITY AT THE LARGEST AIRPORTS IN THE OKLAHOMA CITY STUDY AREA, 1968 (FLIGHTS/YEAR)

Type Aircraft	Will Rogers	Wiley Post	Cimarron	Max Westheimer	Chickasha Municipal
1 Engine Conventional Jet	2,100	--	--	--	--
2 Engine Conventional Jet	8,400	2,600	--	--	--
3 Engine Fan-Jet	11,500	--	--	--	--
4 Engine Fan-Jet	11,500	--	--	--	--
2 Engine Turboprop	--	1,800	--	--	--
1 Engine Piston	29,600	67,200	54,700	55,000	12,700
2 Engine Piston	21,000	16,800	--	4,800	--
4 Engine Piston	14,900	--	--	--	--
TOTAL	99,000	98,400	54,700	59,800	12,700

a = Flight is defined as a combination of a landing and a take-off.

TABLE 11 SOLID WASTE BALANCE FOR THE OKLAHOMA CITY STUDY AREA, 1968

Political Jurisdiction	Total Refuse Generated	On-Site Incineration	Open Burning		Landfills	Non-Burning Dumps
			On-Site	Dumps		
Canadian	40,100	--	3,700	9,800	26,600	--
Cleveland	99,700	--	--	26,400	73,300	--
Grady	27,400	--	5,500	21,900	--	--
Kingfisher	16,100	--	2,000	12,000	--	2,100
Lincoln	17,800	--	3,600	10,500	--	3,700
Logan	23,100	--	1,700	9,800	--	11,600
McClain	12,200	--	4,100	4,000	--	4,100
Oklahoma	364,600	48,700	12,200	61,000	242,700	--
Pottawatomie	53,400	--	9,100	35,200	--	9,100
STUDY AREA	654,400	48,700	41,900	190,600	342,600	30,600

TABLE 12 AIR POLLUTANT EMISSIONS FROM SOLID WASTE DISPOSAL
1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Incineration					
Municipal	--	--	--	--	--
On-Site	50	240	1,070	20	70
Subtotal	50	240	1,070	20	70
Open Burning					
On-Site	20	330	1,780	630	230
Dump	100	1,520	8,090	2,850	1,050
Subtotal	120	1,850	9,870	3,480	1,280
GRAND TOTAL	170	2,090	10,940	3,500	1,350

Incineration

In the Oklahoma City Study Area there were no municipal incinerators used to dispose of solid waste. The amount of refuse disposed of by on-site incineration was assumed to be negligible except in Oklahoma County. In Oklahoma County the 48,000 tons of refuse burned by on-site incinerators was treated as an area source and apportionned onto grids by population. No incinerators were classified as point sources.

The incineration of refuse contributed 30 percent of the total sulfur oxide emissions from solid waste disposal, 11 percent of the particulates, 10 percent of the carbon monoxide, 5 percent of the nitrogen oxides and less than 1 percent of the hydrocarbons.

Open Burning

The two major categories of open burning are open burning dumps and on-site open burning. Open burning dumps are the largest contributors to the air pollution from solid waste disposal. There were 11 open burning dumps in the Study Area that were classified as point sources. They account for 60 percent of the sulfur oxides, 73 percent of the particulates, 74 percent of the carbon monoxide, 81 percent of the hydrocarbons, and 78 percent of the nitrogen oxides.

INDUSTRIAL PROCESSES

The Study Area is notably void of any heavy industrial complexes. From an air pollution standpoint the food and agricultural industry and mineral products industry were by far the most significant industrial process sources. In the food and agriculatural industry the largest sources were 10 grain elevators, 7 feed and grain mills, 1 alfalfa dehydrating plant, 1 coffee roasting plant, 3 fertilizer plants, and 1 cotton seed oil plant. In the mineral products industry the largest sources were 7 asphalt batching plants, 1 asphalt roofing manufacturer, 4 brick manufacturers, 4 concrete batching plants, and 1 glass manufacturer. Other industries that generate air pollutant emissions from their processes include 1 oil reclaiming plant and 1 grey iron foundry. Table 13 presents a summary of the emissions from the various industrial processes.

TABLE 13 AIR POLLUTANT EMISSIONS FROM INDUSTRIAL PROCESSES
1968 (TONS/YEAR)

Source Category	Particulates	Carbon Monoxide
Chemical Process Industry		
Oil Reclaiming	20	--
Food and Agricultural Industry		
Alfalfa Dehydrating	260	--
Coffee Roasting	40	--
Cotton Seed Oil	630	--
Fertilizer	1,150	--
Grain Elevators	2,130	--
Grain Mills	930	--
Subtotal	5,140	--
Metallurgical Industry		
Grey Iron Foundry	10	90
Mineral Products Industry		
Asphalt Batching	570	--
Asphalt Roofing	200	--
Brick Manufacturing	680	--
Concrete Batching	30	--
Glass Manufacturing	180	--
Rock Processing	170	--
Subtotal	1,830	--
GRAND TOTAL	7,000	90

The area included in the Oklahoma City Study Area has a large number of plants in the feed and grain industry. The 10 grain elevators processed more than 7 million bushels of grain in 1968, and the 7 feed and grain mills processed approximately 300,000 tons. Most of these plants are equipped with cyclones to control dust emissions. The primary source of dust emissions from the mills was the cleaning operation, which removes the chaff and dirt before the grain is processed. Receiving, handling and storage operations also contribute to the dust emissions. Approximately 44 percent of the particulates from all industrial processes are emitted from the feed and grain industry.

Approximately 35 thousand tons of fertilizer were processed by the three fertilizer plants in the area. It was assumed that 4 percent of the amount processed was lost as particulate emissions. These three fertilizer plants accounted for 16 percent of the total particulates from industrial processes.

The seven asphalt batching plants in the Study Area produced 600,000 tons of hot mix asphalt in 1968. The asphalt roofing plant processed approximately 100,000 tons of asphalt. These 8 plants accounted for 11 percent of the particulates from industrial processes.

Over 75 million bricks were manufactured by the four plants in the Study Area. It was assumed that all of these plants employed some type of control for dust emissions. These plants accounted for 10 percent of the particulates.

The remaining 20 percent of the particulate emissions from industrial processes was distributed among other minor operations as shown in Table 13.

EVAPORATIVE LOSSES

Four source categories were considered for evaporative losses--automobiles, gasoline storage and handling, the consumption of solvents and petroleum operations. The hydrocarbon emissions from all sources by evaporative losses are shown in Table 14.

TABLE 14 HYDROCARBON EMISSIONS FROM EVAPORATIVE LOSSES
1968 (TONS/YEAR)

Source Category	HC Emissions - Tons/Year
Automobiles	18,840
Gasoline Storage and Handling	3,950
Industrial Solvent Evaporation	3,680
Dry Cleaning	1,470
Miscellaneous Solvent Usage	1,100
LPG Processing Plants	26,670
Crude Production	50,850
Crude Storage	4,830
TOTAL	111,390

Automobiles

Automobile evaporation losses include gas tank and carburetor evaporation and engine crankcase blowby. Since 1963, most new automobiles were equipped with positive crankcase ventilation (PCV) valves that reduce hydrocarbon emissions from the crankcase by about 90 percent. Due to a lag time in the automobile replacement rate, it was assumed that 20 percent of the automobiles were not equipped with PCV valves.

The hydrocarbon emissions from automobiles were calculated from vehicle-mile data and were apportionned onto grids using the same methods as for motor vehicles discussed earlier. Evaporative losses from automobiles accounted for 17 percent of the total hydrocarbon emissions from evaporative losses in the Study Area.

Gasoline Storage and Handling

There are four major points (excluding evaporation from the motor vehicle) of hydrocarbon emissions in the storage and handling of gasoline. They are:

1. Breathing and filling losses from storage tanks
2. Filling losses from loading tank conveyances
3. Filling losses from loading underground storage tanks at service stations
4. Spillage and filling losses in filling automobile gas tanks at service stations.

Approximately 320 million gallons of gasoline were stored in the Study Area in 1968. The evaporative losses from this storage and the subsequent handling of the gasoline accounted for 4 percent of the total evaporative losses.

Consumption of Solvents

This category included the consumption of solvents at dry cleaning plants, industrial solvent usage and the miscellaneous use of solvents by small commercial establishments and domestic units. Organic solvents emitted from

these operations were determined by assuming an emission rate of 4 lb/capita/year for any cleaning plants, 13 lb/capita/year for industries and 3 lb/capita/year for miscellaneous consumption.[9,10] The consumption of solvents by these three categories accounted for 5 percent of the hydrocarbon emissions from evaporative losses.

Petroleum Operations

The Oklahoma City Study Area is saturated with sources of evaporative losses from petroleum operations. These operations include the production of crude oil, crude storage and LPG processing plants.

The largest source of hydrocarbons from these three operations was the production of crude. Over 40 million barrels of crude were produced in the Study Area in 1968. This was approximately 18 percent of the state total. The evaporative losses from the production of crude were estimated at 50,800 tons of hydrocarbons, approximately 45 percent of the total.

From the Oklahoma State Tax Commission, Gross Production Division, it was found that the storage capacity of crude in the Study Area was 890,000 barrels. The crude throughput for the year was 370 million gallons. The evaporative losses from the storage of this crude oil accounted for 4 percent of the total.

There were 16 LPG processing plants in the Study Area which produced over 345 million gallons of LPG. Evaporative losses from these plants are held to a minimum. However, they still contributed approximately 23 percent of the total hydrocarbon emission from evaporative loss sources.

EMISSIONS BY JURISDICTION

The previous section presented the air pollutant emissions by source category. In order to show the contribution of each county to the pollution in the entire Study Area, their emissions are summarized in Tables 15 through 23.

As is expected due to a higher degree of urbanization than the other counties, Oklahoma County contributes the majority of air pollutants. Oklahoma County accounts for 70 percent of the total sulfur oxides in the Study Area, 46 percent of the particulates, 75 percent of the carbon monoxide, 34 percent of the hydrocarbons, and 79 percent of the nitrogen oxides.

TABLE 15 SUMMARY OF AIR POLLUTANT EMISSIONS IN CANADIAN COUNTY
1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	100	170	15,180	1,290	1,120
Other	10	30	2,090	440	140
Subtotal	110	200	17,270	1,730	1,260
Stationary Fuel Combustion					
Industry	N	N	N	N	10
Steam-Electric	--	--	--	--	--
Residential	N	20	N	N	80
Commercial and Institutional	N	N	N	N	20
Subtotal	N	20	N	N	110
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	10	110	580	200	70
Subtotal	10	110	580	200	70
Process Losses	N	1,620	N	N	N
Evaporative Losses	--	--	--	1,630	--
GRAND TOTAL[a]	120	1,950	17,900	3,560	1,440

N = Negligible

a = Totals have been rounded.

TABLE 16 SUMMARY OF AIR POLLUTANT EMISSIONS IN CLEVELAND COUNTY 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	150	260	25,580	2,130	1,740
Other	20	60	2,760	600	230
Subtotal	170	320	28,340	2,730	1,970
Stationary Fuel Combustion					
Industry	N	10	N	N	140
Steam-Electric	--	--	--	--	--
Residential	N	20	N	N	120
Commercial and Institutional	N	10	N	N	70
Subtotal	N	40	N	N	330
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	10	210	1,120	400	150
Subtotal	10	210	1,120	400	150
Process Losses	N	80	N	N	N
Evaporative Losses	--	--	--	9,920	--
GRAND TOTALS[a]	180	650	29,500	13,100	2,450

N = Negligible

a = Totals have been rounded.

TABLE 17 SUMMARY OF AIR POLLUTANT EMISSIONS IN GRADY COUNTY 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	70	120	11,190	940	780
Other	10	20	490	120	60
Subtotal	80	140	11,680	1,060	840
Stationary Fuel Combustion					
Industry	N	N	N	N	10
Steam-Electric	--	--	--	--	--
Residential	N	20	N	N	100
Commercial and Institutional	N	N	N	N	20
Subtotal	N	20	N	N	130
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	10	220	1,160	410	150
Subtotal	10	220	1,160	410	150
Process Losses	N	1,100	N	N	N
Evaporative Losses	--	--	--	15,140	--
GRAND TOTALS[a]	90	1,480	12,800	16,600	1,120

N = Negligible

a = Totals have been rounded.

TABLE 18 SUMMARY OF AIR POLLUTANT EMISSIONS IN KINGFISHER COUNTY, 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	40	60	6,710	550	430
Other	N	10	N	10	20
Subtotal	40	70	6,710	560	450
Stationary Fuel Combustion					
Industry	N	N	N	N	N
Steam-Electric	--	--	--	--	--
Residential	N	N	N	N	10
Commercial and Institutional	N	N	N	N	10
Subtotal	N	N	N	N	50
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	10	110	600	210	80
Subtotal	10	110	600	210	80
Process Losses	N	780	N	N	N
Evaporative Losses	--	--	--	20,300	--
GRAND TOTALS[a]	50	960	7,310	21,100	580

N = Negligible

a = Totals have been rounded.

TABLE 19 SUMMARY OF AIR POLLUTANT EMISSIONS IN LINCOLN COUNTY 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	50	90	8,160	700	610
Other	N	10	10	20	30
Subtotal	50	100	8,170	720	640
Stationary Fuel Combustion					
Industry	N	N	N	N	N
Steam-Electric	--	--	--	--	--
Residential	N	N	N	N	60
Commercial and Institutional	N	N	N	N	N
Subtotal	N	N	N	N	60
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	10	110	600	210	80
Subtotal	10	110	600	210	80
Process Losses	N	300	N	N	N
Evaporative Losses	--	--	--	10,190	--
GRAND TOTALS[a]	60	510	8,770	11,100	780

N = Negligible

a = Totals have been rounded.

TABLE 20 SUMMARY OF AIR POLLUTANT EMISSIONS IN LOGAN COUNTY 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	40	80	7,580	630	520
Other	N	10	10	10	20
Subtotal	40	90	7,590	640	540
Stationary Fuel Combustion					
Industry	N	N	N	N	10
Steam-Electric	--	--	--	--	--
Residential	N	N	N	N	50
Commercial and Institutional	N	N	N	N	10
Subtotal	N	N	N	N	70
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	N	80	450	160	60
Subtotal	N	80	450	160	60
Process Losses	N	30	N	N	N
Evaporative Losses	--	--	--	4,090	--
GRAND TOTALS	40	200	8,040	4,890	670

N = Negligible

TABLE 21 SUMMARY OF AIR POLLUTANT EMISSIONS IN McCLAIN COUNTY 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	30	60	5,790	480	400
Other	N	10	N	10	20
Subtotal	30	70	5,790	490	420
Stationary Fuel Combustion					
Industry	N	N	N	N	N
Steam-Electric	--	--	--	--	--
Residential	10	N	N	N	40
Commercial and Institutional	N	N	N	N	N
Subtotal	10	N	N	N	40
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	N	60	350	120	40
Subtotal	N	60	350	120	40
Process Losses	N	220	N	N	N
Evaporative Losses	--	--	--	10,380	--
GRAND TOTAL[a]	40	250	6,140	11,000	500

N = Negligible

a = Totals have been rounded

TABLE 22 SUMMARY OF AIR POLLUTANT EMISSIONS IN OKLAHOMA COUNTY
1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	1,300	2,270	301,560	23,170	15,250
Other	120	570	14,060	3,290	1,460
Subtotal	1,420	2,840	315,620	26,460	16,710
Stationary Fuel Combustion					
Industry	N	80	N	N	920
Steam-Electric	10	560	N	N	14,440
Residential	10	180	N	N	1,200
Commercial and Institutional	N	90	N	N	530
Subtotal	20	910	N	N	17,090
Refuse Disposal					
Incineration	50	240	1,070	20	70
Open Burning	40	590	3,130	1,100	400
Subtotal	90	830	4,400	1,120	470
Process Losses	N	2,000	90	N	N
Evaporative Losses	--	--	--	33,650	--
GRAND TOTAL[a]	1,530	6,580	320,100	51,200	34,300

N = Negligible

a = Totals have been rounded.

TABLE 23 SUMMARY OF AIR POLLUTANT EMISSIONS IN POTTAWATOMIE COUNTY, 1968 (TONS/YEAR)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	100	180	17,520	1,470	1,220
Other	10	30	10	30	60
Subtotal	110	210	17,530	1,500	1,280
Stationary Fuel Combustion					
Industry	N	N	N	N	20
Steam-Electric	--	--	--	--	--
Residential	10	10	N	N	100
Commercial and Institutional	N	N	N	N	20
Subtotal	10	10	N	N	140
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	20	350	1,880	660	240
Subtotal	20	350	1,880	660	240
Process Losses	N	910	N	N	N
Evaporative Losses	--	--	--	6,080	--
GRAND TOTAL[a]	40	1,490	19,400	8,240	1,660

N = Negligible

a = Totals have been rounded.

EMISSIONS BY GRID

For the purpose of defining the geographical variation of air pollutant emissions in the Study Area, the resulting emissions were apportionned on the grid coordinate system. The emissions were divided into two source groups--point and area sources. Fourty-eight point sources are identified individually with respect to location and emissions. Each of these point sources emitted more than 0.5 tons per average annual day of any pollutant.

CONTRIBUTIONS OF POINT AND AREA SOURCES

Figure 5 shows the location of all point sources in the area. Collectively the fourty-eight point sources account for 55 percent of particulate matter, 37 percent of nitrogen oxides , 21 percent of the hydrocarbons, and only 6 percent of the carbon monoxide and 0 percent of the sulfur oxides. The percentage contribution to carbon monoxide and sulfur oxides emissions is low because motor vehicles, which are area sources, contribute 84 percent of the total sulfur oxide emissions and 93 percent of the total carbon monoxide emissions. Similarly, the contribution to total hydrocarbon emissions is low since two groups of area sources, motor vehicles and evaporative losses are the major sources. Table 24 presents the emissions of point sources. Each source is identified by source category, grid number and horizontal and vertical coordinates. The emissions of sulfur oxides, particualtes, carbon monoxide, hydrocarbons, and nitrogen oxides are shown for an average annual day, average winter day (December, January, February), and average summer day (June, July, August). The appendix presents the method of calculating these three averages.

Area sources are sources of emissions that are insignificant by themselves, but as a group may emit a large portion of the areas total pollution. Examples of area sources are motor vehicles, residences, light commercial and industrial establishments and backyard burning. The emissions from area

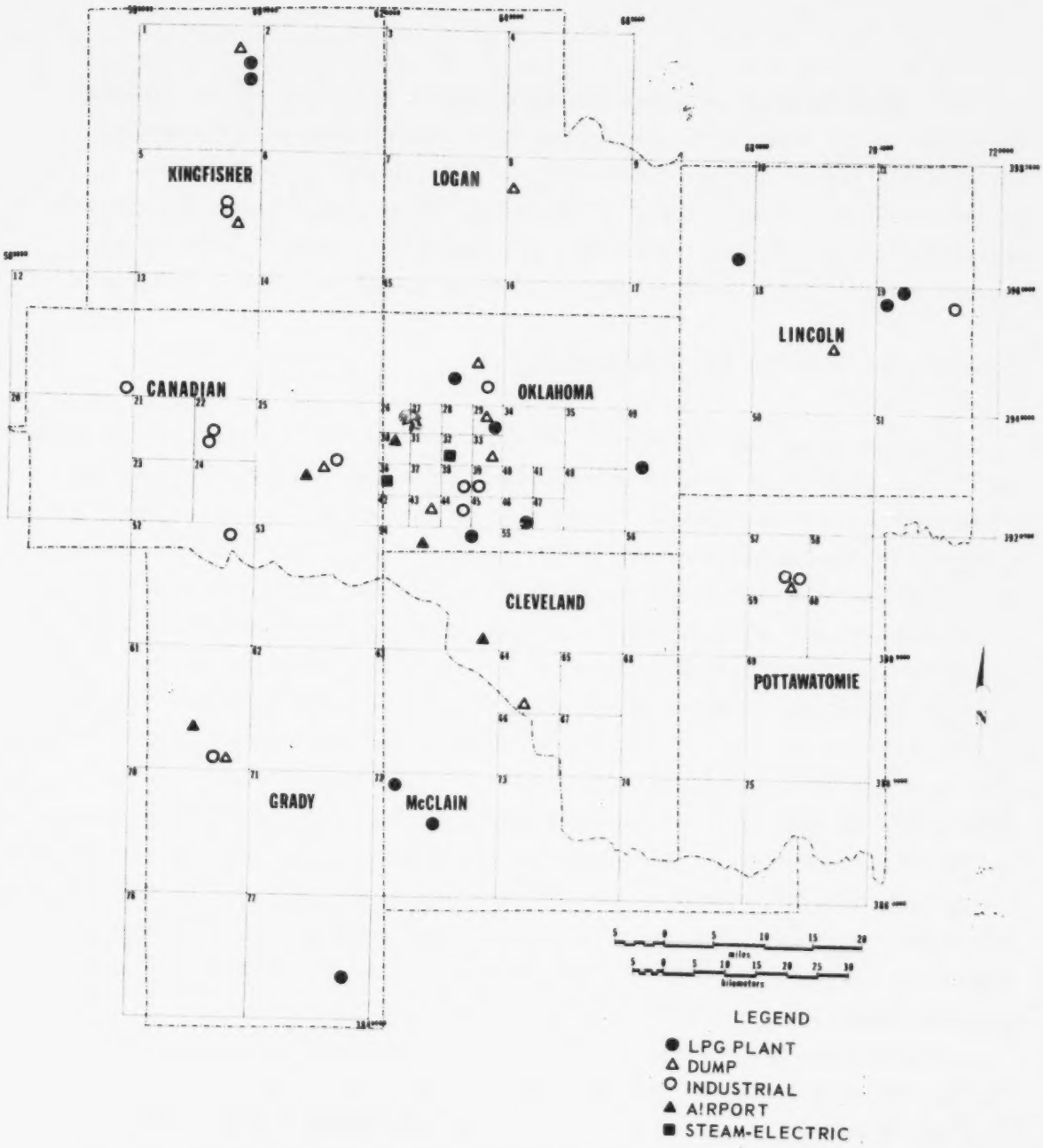

Figure 5. Point source locations for the Oklahoma City study area.

sources have been added to that for point sources to obtain total emissions from all sources by grid, as shown in Table 25. The emissions from all sources are also shown for an annual average, winter and summer day.

EMISSION DENSITIES

In order to provide a visual representation of the emissions of pollutants by grids, emission density maps have been prepared. Emission densities were obtained by summing the annual area and point source emissions for each grid and dividing this total by the land area of the grid. Figures 6 through 10 show the variation in emission densities for the respective grids throughout the Study Area. As expected the emissions generally follow the pattern and degree of urbanization. Emission densities for carbon monoxide and nitrogen oxides are higher in the grids with the higher populations and corresponding higher vehicular activity. Particulate emissions are high only in areas where industries are located. Hydrocarbon emission densities are highest in grids where gas processing plants are located and in grids which contain a large number of crude oil wells. Sulfur oxide emission densities are not shown because of the extremely low values.

TABLE 24 SUMMARY OF AIR POLLUTANT EMISSIONS FROM POINT SOURCES IN THE OKLAHOMA CITY STUDY AREA, 1968 (TONS/DAY)

Source Category	Grid	HC	VC	SOx			PART.			CO			HC			NOx		
				S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
LPG Plant	1	5990	39950	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	3.04	3.04	3.04	0.00	0.00	0.00
LPG Plant	1	5990	39960	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	13.90	13.90	13.90	0.00	0.00	0.00
Dump	1	5980	39980	0.0	0.0	0.0	0.14	0.14	0.14	0.76	0.76	0.76	0.26	0.26	0.26	0.09	0.09	0.09
Industrial	5	5950	39724	0.0	0.0	0.0	0.56	0.56	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	5	5950	39726	0.0	0.0	0.0	0.84	0.84	0.84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dump	5	5970	39720	0.0	0.0	0.0	0.11	0.11	0.11	0.61	0.61	0.61	0.21	0.21	0.21	0.07	0.07	0.07
Dump	8	6401	39750	0.0	0.0	0.0	0.16	0.16	0.16	0.87	0.87	0.87	0.30	0.30	0.30	0.11	0.11	0.11
LPG Plant	9	6780	39630	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.99	0.99	0.99	0.00	0.00	0.00
Industrial	12	5797	39405	0.0	0.0	0.0	0.70	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	15	6370	39430	0.0	0.0	0.0	0.62	0.62	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dump	15	6350	39480	0.0	0.0	0.0	0.30	0.30	0.30	1.59	1.59	1.59	0.56	0.56	0.56	0.20	0.20	0.20
LPG Plant	15	6308	39449	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	15.60	15.60	15.60	0.00	0.00	0.00
Dump	18	6920	39500	0.0	0.0	0.0	0.15	0.15	0.15	0.82	0.82	0.82	0.29	0.29	0.29	0.10	0.10	0.10
LPG Plant	19	7030	39590	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.72	0.72	0.00	0.00	0.00
LPG Plant	19	7020	39570	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	2.67	2.67	2.67	0.00	0.00	0.00
Industrial	19	7120	39580	0.0	0.0	0.0	0.55	0.55	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	22	5930	39340	0.0	0.0	0.0	0.80	0.80	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	22	5920	39330	0.0	0.0	0.0	0.70	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	25	6120	39320	0.0	0.0	0.0	1.04	1.04	1.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dump	25	6100	39320	0.0	0.0	0.0	0.19	0.19	0.19	1.05	1.05	1.05	0.37	0.37	0.37	0.13	0.13	0.13
Airport	25	6070	39290	0.0	0.0	0.0	0.02	0.02	0.02	5.69	5.69	5.69	1.12	1.12	1.12	0.26	0.26	0.26

TABLE 24 SUMMARY OF AIR POLLUTANT EMISSIONS FROM POINT SOURCES (cont.)

Source Category	Grid	HC	VC	SOx			PART.			CO			HC			NOx		
				S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
LPG Plant	29	6380	39355	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	1.58	1.58	1.58	0.00	0.00	0.00
Dump	29	6370	39360	0.0	0.0	0.0	0.37	0.37	0.37	1.97	1.97	1.97	0.69	0.69	0.69	0.25	0.25	0.25
Airport	30	6230	39340	0.0	0.0	0.0	0.12	0.12	0.12	13.21	13.21	13.21	2.54	2.54	2.54	0.65	0.65	0.65
Steam-Electric	32	6327	39324	0.0	0.0	0.0	0.04	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	1.07	0.60	0.50
Dumps	33	6380	39330	0.0	0.0	0.0	0.51	0.51	0.51	2.75	2.75	2.75	0.97	0.97	0.97	0.35	0.35	0.35
Steam-Electric	36	6203	39258	0.0	0.0	0.0	0.71	0.65	0.67	0.00	0.00	0.00	0.00	0.00	0.00	18.48	17.05	17.52
Industrial	38	6329	39258	0.0	0.0	0.0	0.82	0.82	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	39	6352	39251	0.0	0.0	0.0	1.71	1.71	1.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dump	43	6283	39235	0.0	0.0	0.0	0.12	0.12	0.12	0.68	0.68	0.68	0.24	0.24	0.24	0.08	0.08	0.08
Industrial	44	6348	39223	0.0	0.0	0.0	0.82	0.82	0.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPG Plant	46	6440	39205	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	3.59	3.59	3.59	0.00	0.00	0.00
LPG Plant	49	6640	39310	0.0	0.0	0.0	1.17	0.70	0.82	0.00	0.00	0.00	0.00	0.00	0.00	30.57	18.34	21.54
Industrial	52	5951	39180	0.0	0.0	0.0	0.69	0.69	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPG Plant	54	6360	39190	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	2.46	2.46	2.46	0.00	0.00	0.00
Airport	54	6370	39020	0.0	0.0	0.0	0.03	0.03	0.03	7.48	7.48	7.48	1.45	1.45	1.45	0.34	0.34	0.34
Airport	54	6275	39177	0.0	0.0	0.0	0.53	0.53	0.53	24.81	24.81	24.81	5.33	5.33	5.33	1.52	1.52	1.52
Industrial	57	6880	39120	0.0	0.0	0.0	0.78	0.78	0.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industrial	57	6860	39130	0.0	0.0	0.0	0.70	0.70	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dump	57	6870	39103	0.0	0.0	0.0	0.71	0.71	0.71	3.80	3.80	3.80	1.34	1.34	1.34	0.49	0.49	0.49
Industrial	61	5950	38820	0.0	0.0	0.0	2.73	2.73	2.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dump	61	5950	38820	0.0	0.0	0.0	0.32	0.32	0.32	1.74	1.74	1.74	0.61	0.61	0.61	0.22	0.22	0.22
Airport	61	5910	38850	0.0	0.0	0.0	0.00	0.00	0.00	1.32	1.32	1.32	0.26	0.26	0.26	0.06	0.06	0.06
Dumps	64	6440	38910	0.0	0.0	0.0	0.54	0.54	0.54	2.87	2.87	2.87	1.01	1.01	1.01	0.37	0.37	0.37
LPG Plant	72	6270	38740	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	4.77	4.77	4.77	0.00	0.00	0.00
LPG Plant	72	6230	38780	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	1.07	1.07	1.07	0.00	0.00	0.00
LPG Plant	77	6170	38430	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	21.40	21.40	21.40	0.00	0.00	0.00

TABLE 25 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES IN THE OKLAHOMA CITY STUDY AREA 1968, (TONS/DAY)

Grid	Land Area (Sq. Mi.)	SOx			PART.			CO			HC			NOx		
		S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
1	154.4	0.0	0.0	0.0	0.5	0.5	0.5	4.9	4.2	4.6	26.9	26.7	26.8	0.5	0.5	0.5
2	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.7	1.8	4.7	4.6	4.6	0.2	0.2	0.2
3	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.0	1.1	0.8	0.8	0.8	0.1	0.1	0.1
4	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.9	0.9	0.7	0.7	0.7	0.1	0.1	0.1
5	154.4	0.1	0.1	0.1	2.1	2.1	2.1	10.8	9.0	9.9	18.4	18.2	18.3	0.8	0.7	0.7
6	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.7	2.2	2.4	4.8	4.7	4.8	0.2	0.2	0.2
7	154.4	0.0	0.0	0.0	0.0	0.0	0.0	3.4	2.8	3.1	2.0	1.9	1.9	0.3	0.3	0.2
8	154.4	0.1	0.1	0.1	0.5	0.5	0.5	16.7	13.9	15.3	9.4	9.0	9.2	1.3	1.3	1.3
9	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.5	1.2	1.3	2.4	2.3	2.3	0.1	0.1	0.1
10	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.5	1.7	2.1	2.1	2.1	0.2	0.2	0.2
11	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.0	1.1	1.4	1.3	1.4	0.1	0.1	0.1
12	154.4	0.0	0.0	0.0	0.7	0.7	0.7	1.1	0.9	1.0	0.3	0.2	0.2	0.1	0.1	0.1
13	154.4	0.0	0.0	0.0	0.1	0.1	0.1	3.7	3.0	3.4	2.9	2.8	2.8	0.3	0.3	0.3
14	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.7	1.9	1.3	1.2	1.3	0.2	0.2	0.2
15	154.4	0.1	0.1	0.1	1.2	1.2	1.2	19.0	15.9	17.4	19.5	19.1	19.3	1.3	1.4	1.3
16	154.4	0.2	0.1	0.1	0.3	0.2	0.3	30.3	24.8	27.5	4.3	3.6	4.0	1.8	1.6	1.7
17	154.4	0.1	0.0	0.0	0.1	0.1	0.1	8.9	7.3	8.1	3.0	2.8	2.9	0.6	0.5	0.6
18	154.4	0.1	0.0	0.0	0.3	0.2	0.2	6.4	5.4	5.9	6.2	6.1	6.1	0.6	0.5	0.5
19	154.4	0.0	0.0	0.0	1.0	1.0	1.0	5.3	4.4	4.9	9.5	9.3	9.4	0.5	0.5	0.5
20	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.9	1.0	0.2	0.2	0.2	0.1	0.1	0.1
21	38.6	0.0	0.0	0.0	0.0	0.0	0.0	1.3	1.1	1.2	0.2	0.2	0.2	0.1	0.1	0.1
22	38.6	0.1	0.1	0.1	1.8	1.8	1.8	23.6	19.4	21.5	4.3	3.7	4.0	1.7	1.6	1.7

TABLE 25 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES (cont.)

Grid	Land Area (Sq. Mi.)	SOx			PART.			CO			HC			NOx		
		S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
23	38.6	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	0.9	0.2	0.2	0.2	0.1	0.1	0.1
24	38.6	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.0	1.1	0.2	0.2	0.2	0.1	0.1	0.1
25	154.4	0.1	0.1	0.1	1.4	1.4	1.4	16.2	14.5	15.3	3.4	3.1	3.2	1.2	1.2	1.2
26	9.6	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.9	2.1	0.4	0.3	0.3	0.2	0.1	0.2
27	9.6	0.0	0.0	0.0	0.1	0.1	0.1	5.3	4.4	4.8	1.0	0.8	0.9	0.4	0.4	0.4
28	9.6	0.1	0.1	0.1	0.2	0.3	0.2	14.1	11.5	12.8	3.4	3.1	3.2	1.0	1.3	1.1
29	9.6	0.0	0.0	0.0	0.4	0.4	0.4	5.5	4.9	5.2	2.8	2.7	2.7	0.5	0.4	0.5
30	9.6	0.1	0.0	0.1	0.3	0.3	0.3	22.6	20.9	21.8	4.6	4.4	4.5	1.3	1.4	1.4
31	9.6	0.3	0.3	0.3	0.9	0.9	0.9	77.5	63.4	70.4	10.6	8.9	9.7	4.0	3.7	3.8
32	9.6	0.3	0.3	0.3	0.6	0.6	0.6	63.8	52.3	58.0	9.9	8.6	9.3	4.5	4.2	3.9
33	9.6	0.2	0.2	0.2	0.9	0.9	0.9	50.5	41.9	46.2	7.4	6.4	6.9	2.8	2.6	2.7
34	38.6	0.1	0.1	0.1	0.2	0.2	0.2	15.8	13.0	14.4	2.9	2.5	2.7	1.0	1.1	1.1
35	38.6	0.0	0.0	0.0	0.1	0.1	0.1	4.3	3.5	3.9	0.9	0.8	0.9	0.3	0.3	0.3
36	9.6	0.1	0.1	0.1	0.9	0.8	0.8	12.4	10.2	11.3	2.1	1.8	2.0	19.2	17.8	18.2
37	9.6	0.3	0.2	0.2	0.6	0.7	0.6	54.3	44.5	49.4	8.8	7.6	8.2	3.0	3.2	3.1
38	9.6	0.5	0.4	0.4	2.3	2.4	2.3	124.8	102.2	113.5	17.8	15.4	16.6	5.6	5.9	5.6
39	9.6	0.4	0.3	0.3	3.0	3.0	3.0	71.8	58.8	65.3	12.3	10.8	11.5	4.1	4.4	4.1
40	9.6	0.1	0.1	0.1	0.3	0.3	0.3	27.2	22.3	24.8	4.6	4.0	4.3	1.5	1.7	1.6
41	9.6	0.1	0.1	0.1	0.1	0.1	0.1	11.7	9.6	10.6	2.0	1.7	1.8	0.7	0.7	0.7
42	9.6	0.0	0.0	0.0	0.0	0.0	0.0	1.7	1.4	1.5	0.3	0.2	0.3	0.1	0.1	0.1
43	9.6	0.1	0.1	0.1	0.4	0.4	0.4	22.6	18.7	20.6	3.8	3.4	3.6	1.4	1.4	1.4
44	9.6	0.4	0.3	0.3	1.6	1.7	1.6	96.2	78.8	87.5	13.8	11.9	12.9	4.3	4.6	4.4

TABLE 25 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES (cont.)

Grid	Land Area (Sq. Mi.)	SOx S	SOx W	SOx A	PART. S	PART. W	PART. A	CO S	CO W	CO A	HC S	HC W	HC A	NOx S	NOx W	NOx A
45	9.6	0.2	0.2	0.2	0.4	0.4	0.4	41.4	33.9	37.7	7.0	6.2	6.6	2.3	2.4	2.3
46	9.6	0.3	0.2	0.3	0.6	0.5	0.5	52.7	43.2	47.9	12.0	10.8	11.4	3.3	3.2	3.2
47	9.6	0.1	0.1	0.1	0.2	0.2	0.2	11.3	9.3	10.3	3.0	2.8	2.9	0.9	1.2	1.0
48	38.6	0.1	0.1	0.1	0.1	0.1	0.1	11.8	9.6	10.7	1.9	1.6	1.8	0.7	0.7	0.7
49	154.4	0.1	0.1	0.1	1.3	0.8	0.9	7.2	5.9	6.5	2.5	2.3	2.4	31.1	18.8	22.0
50	154.4	0.0	0.0	0.0	0.1	0.1	0.1	5.4	4.4	4.9	3.8	3.6	3.7	0.4	0.3	0.3
51	154.4	0.0	0.0	0.0	0.1	0.1	0.1	3.6	3.0	3.3	3.6	3.5	3.5	0.3	0.3	0.3
52	154.4	0.0	0.0	0.0	1.3	1.3	1.3	3.7	3.0	3.4	1.8	1.7	1.8	0.3	0.3	0.3
53	154.4	0.0	0.0	0.0	0.1	0.1	0.1	4.4	3.7	4.0	2.1	2.0	2.0	0.4	0.4	0.4
54	154.4	0.5	0.4	0.4	2.0	2.0	2.0	104.7	91.6	98.1	27.9	26.1	27.0	7.4	7.5	7.3
55	154.4	0.4	0.4	0.4	0.9	0.9	0.9	66.0	54.0	60.0	24.0	22.3	23.1	5.1	5.2	5.0
56	154.4	0.0	0.0	0.0	0.1	0.1	0.1	6.7	5.5	6.1	1.7	1.5	1.6	0.5	0.5	0.5
57	38.6	0.2	0.2	0.2	3.7	3.7	2.7	34.1	28.7	31.4	13.4	12.6	13.0	2.8	2.7	2.7
58	38.6	0.0	0.0	0.0	0.0	0.0	0.0	2.0	1.7	1.9	0.8	0.8	0.8	0.2	0.1	0.1
59	38.6	0.1	0.0	0.0	0.2	0.2	0.2	7.9	6.5	7.2	3.1	2.9	3.0	0.6	0.6	0.6
60	38.6	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.3	1.4	0.6	0.6	0.6	0.1	0.1	0.1
61	154.4	0.2	0.1	0.1	3.6	3.6	3.6	23.5	19.9	21.7	14.3	13.8	14.0	1.9	1.9	1.9
62	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.3	1.4	1.0	1.0	1.0	0.1	0.1	0.1
63	154.4	0.0	0.0	0.0	0.2	0.2	0.2	6.6	5.4	6.0	7.0	6.9	6.9	0.5	0.4	0.4
64	38.6	0.0	0.0	0.0	0.8	0.8	0.8	5.7	5.2	5.4	2.0	2.0	2.0	0.6	0.6	0.6
65	38.6	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.9	1.0	0.4	0.4	0.4	0.1	0.1	0.1
66	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.7	0.8	0.7	0.7	0.7	0.1	0.1	0.1

TABLE 25 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES (cont.)

Grid	Land Area (Sq. Mi.)	SOx			PART.			CO			HC			NOx		
		S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
67	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6	0.7	0.3	0.3	0.3	0.1	0.1	0.1
68	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.1	1.7	1.9	0.9	0.9	0.9	0.2	0.2	0.2
69	154.4	0.0	0.0	0.0	0.1	0.1	0.1	3.6	3.0	3.3	1.6	1.5	1.5	0.3	0.3	0.3
70	154.4	0.0	0.0	0.0	0.1	0.1	0.1	1.8	1.5	1.7	1.3	1.3	1.3	0.2	0.2	0.2
71	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.4	1.9	2.2	1.7	1.7	1.7	0.2	0.2	0.2
72	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.4	2.0	2.2	9.2	9.2	9.2	0.2	0.2	0.2
73	154.4	0.1	0.1	0.1	0.3	0.3	0.3	10.1	8.4	9.2	11.9	11.7	11.8	0.9	0.9	0.9
74	154.4	0.0	0.0	0.0	0.0	0.0	0.0	2.3	1.9	2.1	2.3	2.3	2.3	0.2	0.2	0.2
75	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.4	1.2	1.3	0.8	0.8	0.8	0.1	0.1	0.1
76	154.4	0.0	0.0	0.0	0.1	0.1	0.1	2.4	2.0	2.2	1.7	1.7	1.7	0.2	0.2	0.2
77	154.4	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.8	0.9	22.1	22.1	22.1	0.1	0.1	0.1

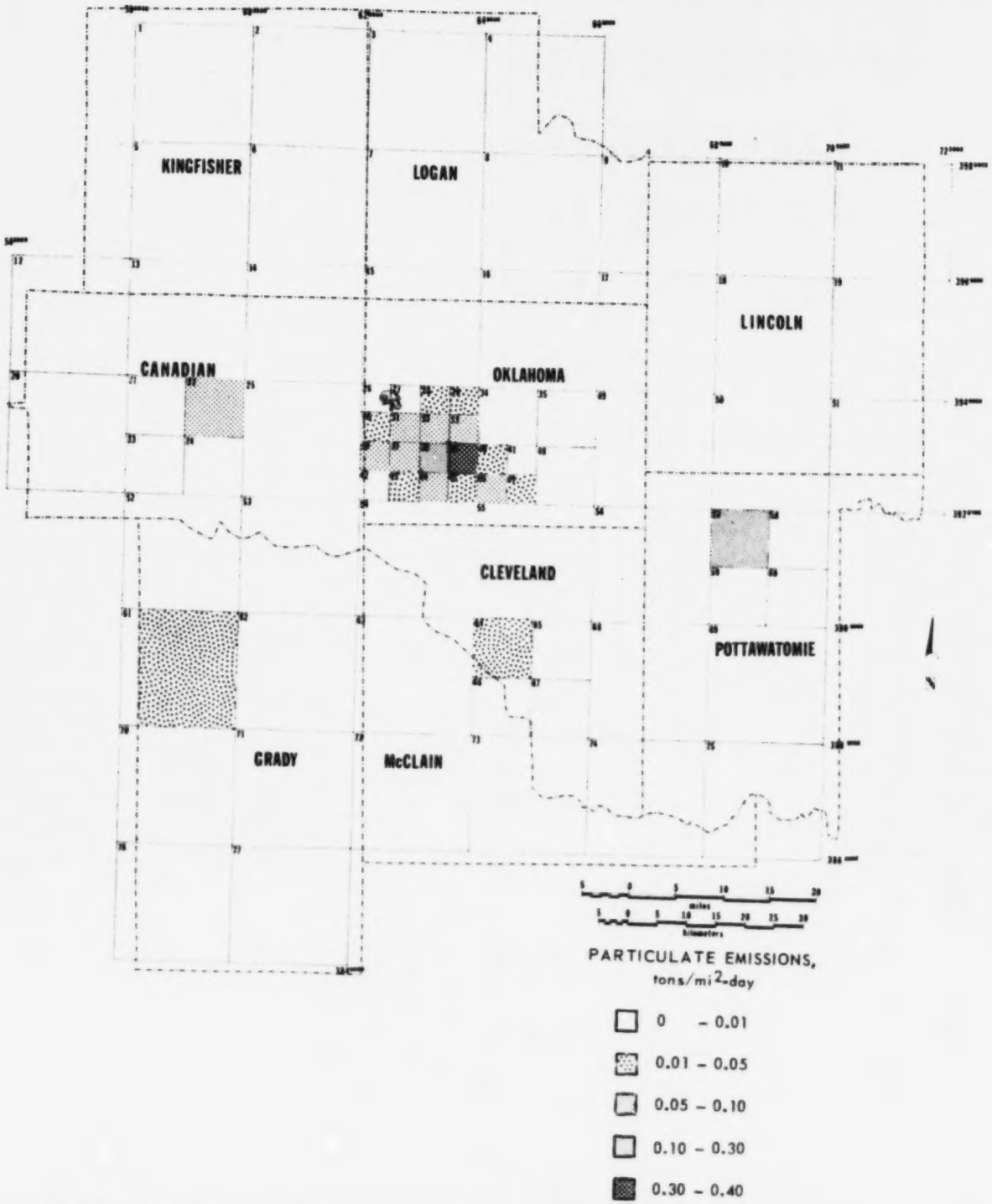

Figure 6. Particulate emissions densities for the Oklahoma City study area, 1968.

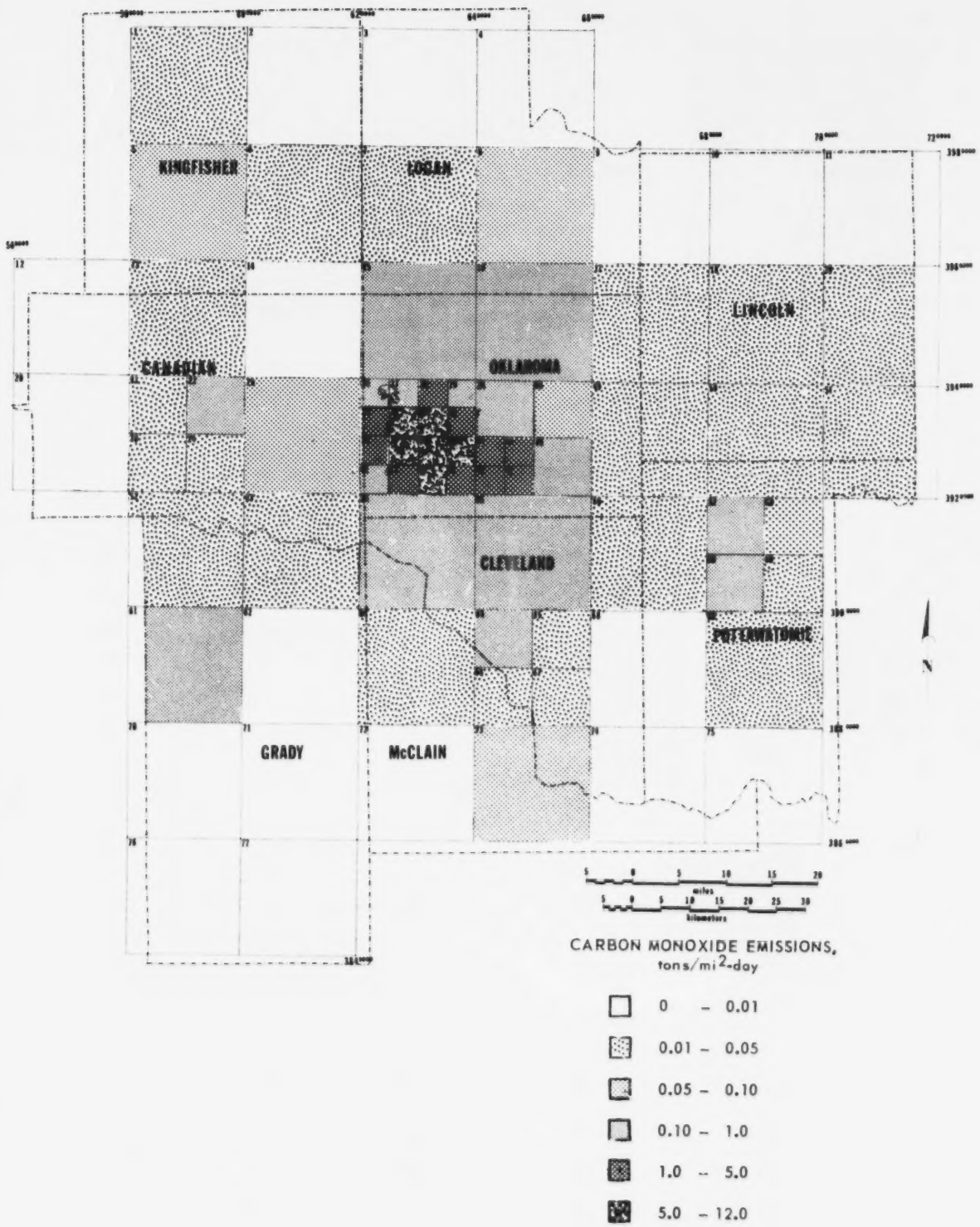

Figure 7. Carbon monoxide emission densities for the Oklahoma City study area, 1968.

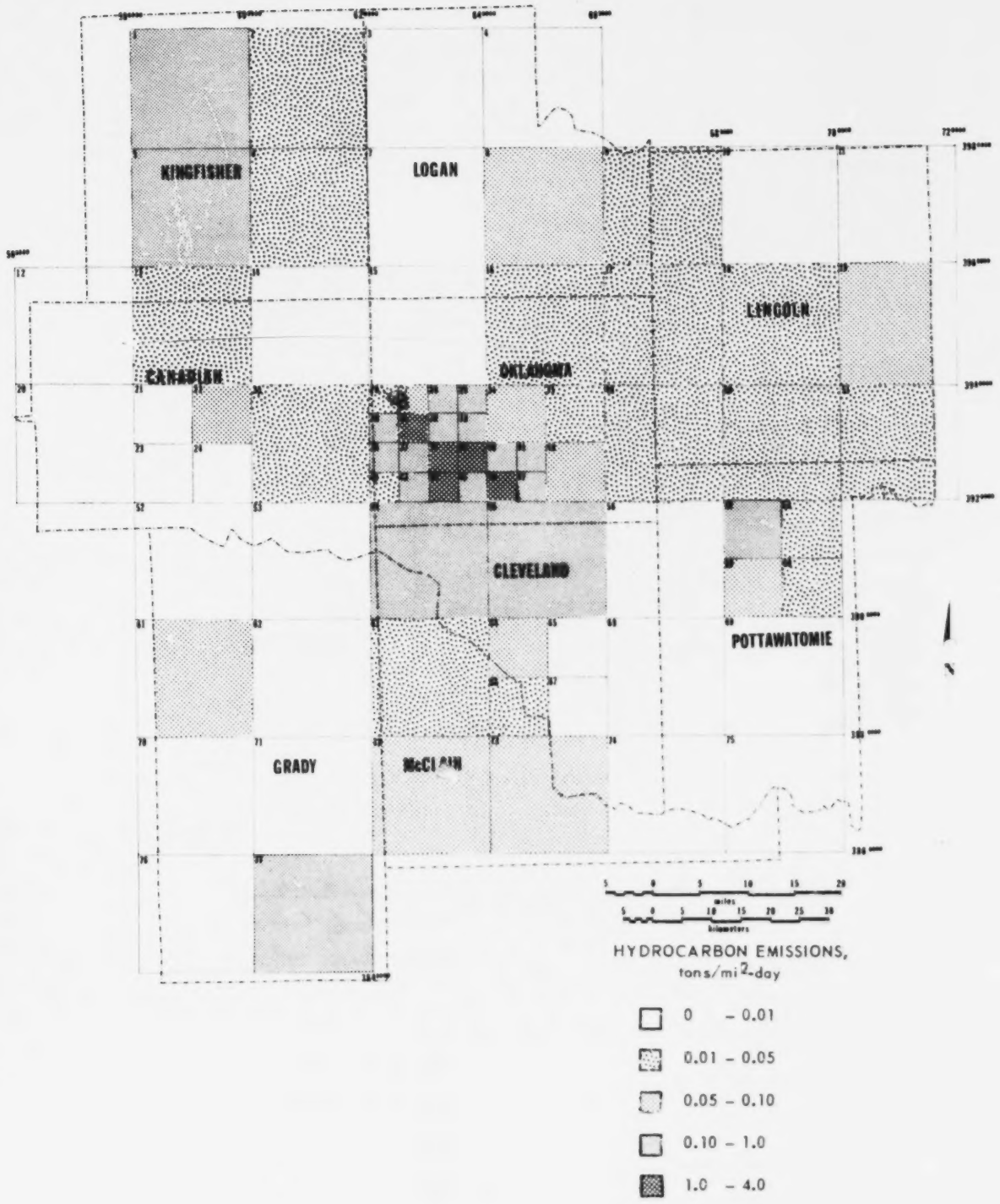

Figure 8. Hydrocarbon emission densities for the Oklahoma City study area, 1968.

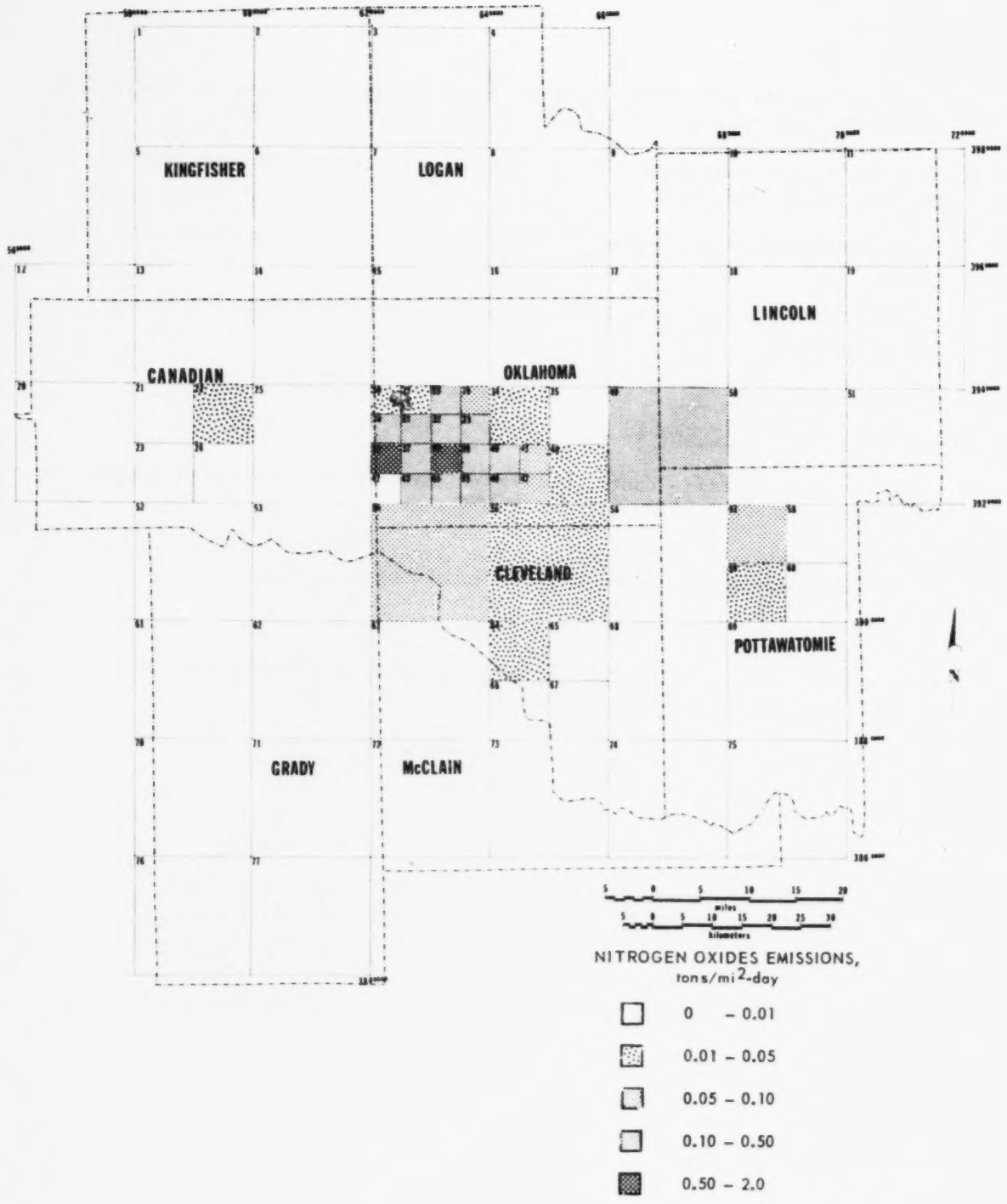

Figure 9. Nitrogen oxides emission densities for the Oklahoma City study area, 1968.

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APPENDIX

METHOD FOR CALCULATING SUMMER, WINTER AND ANNUAL AVERAGE EMISSIONS FOR FUEL CONSUMPTION IN STATIONARY SOURCES

YEARLY AVERAGE (A)

$$A = \frac{\text{Fuel Consumed} \times \text{Emission Factor (E.F.)}}{\text{Days of Operation}}$$

e.g. A plant consumed 100,000 tons of coal in 1967 while operating 365 days. The total degree days for the area was 4,800 and 2,800 for the three winter months. The plant was estimated to use 15 percent of the fuel for space heating and 85 percent for process heating. From this information, the annual average emission for carbon monoxide would be the following:

$$A = \frac{100{,}000 \text{ Tons/year} \times 3 \text{ lbs. CO/Ton coal}}{365 \text{ Days/year} \times 2{,}000 \text{ lb./Ton}}$$

$$A = 0.41 \text{ Ton/Day}$$

WINTER AVERAGE (W)

$$W = \frac{\text{Fuel Consumed} \times \text{E.F.}}{\text{Days of Winter Operation}} \times \frac{\text{Winter Degree Days}}{\text{Total Degree Days}} \times \text{\% Fuel Used for space heating}$$

$$+ \frac{\text{Fuel Consumed} \times \text{E.F.}}{365} \times \text{\% Fuel used for process heating}$$

$$W = \left[\frac{100{,}000 \times 2{,}800}{90 \times 4{,}800} \times 0.15 + \frac{100{,}000}{365} \times 0.85\right] \frac{3}{2{,}000}$$

$$W = 0.49 \text{ Ton/Day}$$

SUMMER AVERAGE (S)

$$S = \frac{\text{Fuel Consumed} \times \text{E.F.}}{\text{Days of Summer Operation}} \times \frac{\text{Summer Degree Days}}{\text{Total Degree Days}} \times \text{\% Fuel Used for space heating}$$

$$+ \frac{\text{Fuel Consumed} \times \text{E.F.}}{365} \times \text{\% Fuel used for process heating}$$

$$S = \left[\frac{100{,}000}{90} \times \frac{0}{4{,}800} \times 0.15 + \frac{100{,}000}{365} \times 0.85\right] \frac{3}{2{,}000}$$

$$S = 0.35 \text{ Ton/Day}$$